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## Distributional Survey And Habitat Associations Of Crayfishes In Three River Basins In Kansas

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DISTRIBUTIONAL SURVEY AND HABITAT  
ASSOCIATIONS OF CRAYFISHES IN  
THREE RIVER BASINS IN KANSAS

being

A Thesis Presented to the Graduate Faculty  
of Fort Hays State University in  
Partial Fulfillment of the Requirements for  
the Degree of Master of Science

by

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the Master of Science degree

by

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## ABSTRACT

Kansas represents the western most edge of high crayfish diversity in North America. The most recent comprehensive survey of crayfishes in Kansas was conducted over 50 years ago and resulted in a list of seven species. Subsequently, three species were added sporadically. The most recent summary of crayfishes in Kansas included 10 species and suggested the highest diversity to be located in the northeastern portion of the state. I surveyed crayfishes in three river basins in Kansas during the summers of 2009, 2010, and 2011: Kansas-Lower Republican, Missouri, and Upper Republican. Sites were selected based on stream order and partitioned among three macrohabitat types (pool, riffle, and run). A total of 132 sites were surveyed and 9,858 crayfishes were documented and represented six species (*Cambarus diogenes*, *Orconectes immunis*, *O. luteus*, *O. neglectus*, *O. virilis*, and *Procambarus simulans*). *Orconectes virilis* was the predominant species collected and exhibited an affinity for pools and runs. *Orconectes immunis* rarely was collected and was restricted to stagnant streams with minimal flow. New distributional records were documented for four species: *C. diogenes*, *O. luteus*, *O. neglectus*, and *P. simulans*. Study results have implications for future evaluation of crayfish communities in Kansas.

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## TABLE OF CONTENTS

	Page
GRADUATE COMMITTEE APPROVAL.....	i
ABSTRACT.....	ii
ACKNOWLEDGMENTS .....	iii
TABLE OF CONTENTS.....	iv
LIST OF TABLES .....	v
LIST OF FIGURES .....	vi
LIST OF APPENDIXES.....	viii
INTRODUCTION .....	1
METHODS .....	4
<i>Study Area</i> .....	4
<i>Survey Protocol</i> .....	5
RESULTS .....	7
DISCUSSION.....	10
<i>Cambarus</i> .....	10
<i>Orconectes</i> .....	11
<i>Procambarus</i> .....	15
CONCLUSIONS.....	16
LITERATURE CITED .....	18

LIST OF TABLES

Table	Page
1. Summary table: Total number of individuals collected and habitat associations, by species in Kansas-Lower Republican, Missouri, and Upper Republican river basins. *Total number of individuals collected and burrows observed .....	23
2. <i>Cambarus diogenes</i> : sites and number of males, females, young-of-year (YOY), and burrows observed .....	24
3. <i>Orconectes virilis</i> : sites and number of males, females, and young-of-year (YOY) collected .....	25
4. <i>Orconectes neglectus</i> : sites and number of males, females, and young-of-year (YOY) collected .....	28
5. <i>Orconectes immunis</i> : sites and number of males, females, and young-of-year (YOY) collected .....	29

## LIST OF FIGURES

Figure	Page
1. Map of survey area stratified by Hydrological Unit Code 8 watersheds. The Upper Republican River Basin indicated in dark gray, Kansas-Lower Republican River Basin indicated in gray, and the Missouri River Basin indicated in light gray. ....	32
2. Map of sites surveyed in the Kansas-Lower Republican, Missouri, and Upper Republican river basins.....	33
3. <i>Cambarus diogenes</i> : <b>A.</b> Map of sites where this species was surveyed. <b>B.</b> Map of survey area indicated in gray. Historical distribution of this species is indicated by black cross-hatch (Williams and Leonard 1952). ....	34
4. <i>Orconectes virilis</i> : <b>A.</b> Map of sites where this species was surveyed. <b>B.</b> Map of survey area indicated in gray. Historical distribution of this species is indicated by black cross-hatch (Williams and Leonard 1952). ....	35
5. <i>Orconectes neglectus</i> : <b>A.</b> Map of sites where this species was surveyed. <b>B.</b> Map of survey area indicated in gray. Historical distribution of this species is indicated by black cross-hatch (Williams and Leonard 1952). ....	36
6. <i>Orconectes immunis</i> : <b>A.</b> Map of sites where this species was surveyed. <b>B.</b> Map of survey area indicated in gray. Historical distribution of this species is indicated by black cross-hatch (Williams and Leonard 1952). ....	37



Figure	Page
7. <i>Orconectes luteus</i> : <b>A.</b> Map of sites where this species was surveyed. <b>B.</b> Map of survey area indicated in gray. Historical distribution of this species is indicated by black cross-hatch (Williams and Leonard 1952). .....	38
8. <i>Procambarus simulans</i> : <b>A.</b> Map of sites where this species was surveyed. <b>B.</b> Map of survey area indicated in gray. Historical distribution of this species is indicated by black cross-hatch (Williams and Leonard 1952). .....	39
9. <i>Procambarus gracilis</i> : <b>A.</b> Map of sites where this species was surveyed. <b>B.</b> Map of survey area indicated in gray. Historical distribution of this species is indicated by black cross-hatch (Williams and Leonard 1952). .....	40

LIST OF APPENDIXES

Appendix	Page
A SURVEY SITE DESCRIPTIONS.....	41

## Introduction

Freshwater crayfishes are distributed worldwide, with exceptions in Antarctica and Southern Asia. There are currently over 640 described species of freshwater crayfishes, with centers of diversity in southeastern United States and southeastern Australia (Crandall and Buhay 2008). Taxonomically, they are organized into two superfamilies: Astacoidea and Parastacoidea. Astacoidea is distributed throughout the Northern Hemisphere and contains two families: Cambaridae and Astacidae. Cambaridae is the most diverse family of crayfish consisting of over 420 species within 12 genera. Astacidae is a much less diverse family, comprised of 39 species within six genera (Hobbs 1989; Taylor et. al. 2007). Parastacoidea are distributed throughout the Southern Hemisphere and is composed of only one family, Parastacidae, containing over 170 species within 15 genera (Taylor et. al. 2007).

Crayfish are a significant component of aquatic ecosystems and dominate macroinvertebrate biomass in streams. Crayfish constitute as high as 400g wet weight biomass  $m^{-2}$  and reach densities of 33 individuals  $m^{-2}$  (Momot et.al. 1978). Because crayfish often comprise a large portion of the macroinvertebrate biomass they can have a significant impact in stream ecosystem processes, and often are considered ecosystem engineers. Ecosystem engineers are classified as organisms that affect ecosystem processes by altering the rates at which resources are available to other species or by altering and creating habitats within their environment (Jones et. al. 1994). Crayfish accelerate detrital processing rates, alter macroinvertebrate community structure, and

create habitat via burrowing (Creed 1994; Charlebois and Lamberti 1996; Statzner et.al. 2000; Hobbs III 2001; Evans-White et. al. 2003; Usio and Townsend 2004).

Crayfish occur in a variety of habitats and are classified as burrowers and non-burrowers. Burrowing crayfish spend the majority of their life cycle in subterranean burrows consisting of a single shaft or multiple tunnels (Grow and Merchant 1980; Hobbs III and Rewolinski 1985). Burrowing allows crayfishes access to the water table in areas devoid of permanent standing water (i.e., ditches and ephemeral wetlands). Burrows also are found near stream banks, ponds, lakes, and swamps (Grow and Merchant 1980). Non-burrowing crayfish live in permanent waters and reside in shallow excavations under rocks or in the substrate (Berrill and Chenoweth 1982). While crayfish are generally classified as burrowers and non-burrowers, recent studies suggest a more fine-scale separation at the micro- and macrohabitat levels, within these two categories.

DiStefano et. al. (2003) reported that crayfish inhabit all major stream macrohabitats (i.e., pools, riffles, and runs) and noted ontogenetic shifts in macrohabitat use in at least two species. Juveniles inhabited stream margins with shallow depths and low current velocities; in contrast, adult individuals were more abundant in high gradient channel and riffle habitats, taking advantage of nutrient-rich resources and minimize exposure to potential predators. Additionally, Flinders and Magoulick (2003; 2005) attributed crayfish species abundance to microhabitat parameters (i.e., depth, water velocity, substrate composition, and substrate diversity). These studies suggest crayfish have a complex association with biotic and abiotic parameters and result in macro- and microhabitat partitioning.

Habitat segregation and isolating effects of changes in pre- and post-Pleistocene river drainages have been the impetus for crayfish diversity in North America. There are 382 described species of freshwater crayfishes native to North America (Crandall and Buhay 2008). Similar to fishes and freshwater mussels, the highest numbers of freshwater crayfish species are located in the southeastern United States (Warren and Burr 1994; Taylor et. al. 1996; Taylor et. al. 2007). However, due to habitat loss, nonindigenous species, or a paucity of recent distributional information, the conservation status of this taxonomic group in North America appears dire with 48% of species recognized as endangered, threatened, or vulnerable (Taylor et. al. 2007).

The most recent comprehensive survey of crayfish in Kansas was completed over 50 years ago (Williams and Leonard 1952) and resulted in a list of seven species and broad estimates of range distributions. Subsequently, additional members of the Kansas fauna have been added sporadically by Minckley and Deacon (1959), Metcalf and Distler (1961), Beasley and Branson (1971) and Durban III et al. (1994). The most recent summary of crayfish distributions by Ghedotti (1998) included 10 species and suggested the highest diversity in the northeastern portion of the state. This list includes: *Cambarus diogenes* (Devil Crayfish), *Procambarus acutus* (White River Crayfish), *P. gracilis* (Grassland Crayfish), *P. simulans* (Southern Prairie Crayfish), *Orconectes immunis* (Papershell Crayfish), *O. luteus* (Golden Crayfish), *O. macrus* (Neosho Midget Crayfish), *O. neglectus* (Ringed Crayfish), *O. palmeri longimanus* (Grey-speckled Crayfish), and *O. virilis* (Northern Crayfish) (Ghedotti 1998). Taylor et. al. (2007) classified these species

as currently stable however, current population status and distributional information is uncertain within Kansas.

The purpose of this study was to address the following objectives directed towards improving our understanding of crayfishes within Kansas: 1) Document contemporary distributions of crayfishes within the Kansas-Lower Republican, Missouri, and Upper-Republican river basins in Kansas; 2) Assess the environmental factors that influence crayfish presence; and 3) Evaluate the conservation status of crayfishes within the Kansas, Missouri, and Republican river basins in Kansas.

## Methods

### *Study Area*

During the summers of 2009, 2010, and 2011, I surveyed crayfishes in three river basins within Kansas: Kansas-Lower Republican, Missouri, and Upper-Republican river basins (Figure 1). Sites were selected by: 1) stream order, 2) location of historical surveys, 3) accessibility 4) habitat availability.

The Kansas-Lower Republican River Basin is located in northeastern and north-central Kansas and drains an area of 27,454 km<sup>2</sup>. Major tributaries to the Kansas-Lower Republican River Basin include: Big Blue River, Mill Creek, Vermillion Creek, Soldier Creek, Delaware River, Wakarusa River, and Stranger Creek. Major impoundments within this drainage include: Milford, Tuttle Creek, Perry, and Clinton reservoirs. Land use in the region is almost exclusively agriculture with a minor portion of woodland areas.

The Missouri River Basin is located in the northeastern corner of Kansas and drains an area of 4,144 km<sup>2</sup>. Major tributaries to the Missouri River Basin include: Big Nemaha River, Wolf River, and Independence Creek. Major impoundments within this drainage include Pony Creek Lake, Atchison State Fishing Lake, and Wyandotte City Lake. Land use in the region is dominated by cropland and grassland.

The Upper Republican River Basin is located in the northwestern corner of Kansas and drains an area of 12,690 km<sup>2</sup>. Major tributaries to the Upper-Republican River Basin include: Arikaree River, Beaver Creek, Sappa Creek, and Prairie Dog Creek. Major impoundments within this drainage include Atwood Lake and Keith Sebelius Reservoir. Land use in the region is dominated by cropland and grassland.

#### *Survey Protocol*

Survey protocols were modified from Flinders and Magoulick (2003; 2005) and Burskey and Simon (2010). Drainage basins were subcategorized into Hydrologic Unit Code level 8 (HUC 8) watersheds. Subsequently, stream size (i.e., first, second, and third order) was categorized within each HUC 8 watershed as determined by Aquatic Gap data in ArcGIS. Three replicates of each size category (first, second, and third order streams: nine sites total) were surveyed within each HUC 8 watershed in the Kansas-Lower Republican and Missouri river basins. One replicate of each stream order (three sites total) was surveyed in each HUC 8 watershed within the Upper-Republican River Basin. Site locations were marked with GPS-coordinates (WGS 1984) by using a Garmin eTrex GPS unit. At each site, I sampled crayfish in three replicates of each macrohabitat (pool, riffle, and run).

Crayfish were collected from each macrohabitat type with a 4.5-m straight seine with 3-mm mesh. Macrohabitats were seined repeatedly until crayfish yields declined. Crayfish were identified to species (Hobbs 1976; Pflieger 1996), counted, sexed, and returned to the stream. Additionally, stream banks were examined for crayfish burrows. A minimum of two burrows were excavated per site and observed burrows were counted and recorded. Due to the complexity of burrowing activity, burrows within 1 m<sup>2</sup> of each other were considered to be constructed by the same crayfish.

Physical habitat parameters of depth, substrate, and percent canopy cover were estimated for each macrohabitat. Each macrohabitat was divided into four equal sections, producing three transects perpendicular to the stream flow. Wetted-width was measured at each transect and divided by four, resulting in five equidistant locations across the stream per transect (three in-stream locations and two bank locations). Depth and substrate size were measured at each location. Substrate size included seven categories: fine, sand, fine gravel, coarse gravel, cobble, boulder, and bedrock. Percent canopy cover was estimated at each bank and mid-channel location using a convex spherical densiometer.

Substrate diversity was calculated for each macrohabitat using a Simpson's Diversity Index. Logistic regression was used to elucidate relationships between the presence of crayfish species and environmental variables, including substrate diversity, dominant substrate, mean depth, percent canopy cover, macrohabitat type, site, and basin.



## Results

One-hundred-thirty-two sites were surveyed for crayfish among the three river drainages. Seventy-two sites were surveyed in the Kansas-Lower Republican River Basin, 36 sites were surveyed in the Missouri River Basin, and 24 sites were surveyed in the Upper Republican River Basin. Seven sites were devoid of water and 19 sites were unproductive (no crayfish detected) (Figure 2). In the 106 productive sites, 9,607 crayfishes were documented and represented six species. Site names, GPS coordinates, and legal descriptions are presented in Appendix A.

*Cambarus diogenes* were collected in the Missouri River Basin and within the directly adjacent HUC 8 units in the Kansas-Lower Republican River Basin. This species made up 3% (52 individuals and 235 burrows) of the crayfishes sampled (Tables 1, 2). Males made up 43% of the excavated individuals of this species, and females and young-of-year (YOY) comprised 35% and 22%, respectively. *Cambarus diogenes* was collected at 31 sites within the study area (Figure 3). All individuals were dug out of their burrow with exception to two YOY individuals captured in a single riffle in Duck Creek (CRY-044-10). The presence of *C. diogenes* was associated negatively with run habitats (Wald = 13.991, df = 1, p < 0.001).

*Orconectes virilis* was the predominant species collected in the Kansas-Lower Republican, Missouri, and Upper Republican river basins. This species represented 79% (7,550 individuals) of the crayfishes sampled. Young-of-year made up 43% of the individuals collected and males and females comprised 27% and 30%, respectively. *Orconectes virilis* was collected at 97 sites throughout the study area (Tables 1, 3). This

species was sampled in all HUC 8 units, with exception of two units in the Upper Republican River Basin (Figure 4). These sites were classified as either devoid of water or were sampled and yielded no crayfish. The presence of *O. virilis* was associated positively with pool (Wald = 45.535, df = 1, p < 0.001) and run (Wald = 38.991, df = 1, p < 0.001) macrohabitats.

*Orconectes neglectus* was collected in the Kansas-Lower Republican and Upper Republican river basins. This species represented 13% (1,254 individuals) of the crayfishes sampled. Adult males and females comprised the majority of captures of this species; 35% and 35%, respectively (Tables 1, 4). Young-of-year *O. neglectus* made up 30% of individuals captured. I collected *O. neglectus* at 18 sites in the Kansas-Lower Republican and Upper Republican river basins (Figure 5). Two sites were sampled within this species' expected range, both yielding *O. neglectus*. *Orconectes neglectus* was collected at an additional 12 sites in the Kansas-Lower Republican River Basin and four sites in the Upper Republican River Basin. Within the Upper Republican River Basin, *O. neglectus* was restricted to the South Fork Republican River and portions of Beaver Creek that were supported by permanent flows. This species previously was documented in the Upper Republican River Basin in Kansas in 1900, but no records have been documented since. The presence of *O. neglectus* was associated negatively with mean depth (Wald = 6.590, df = 1, p = 0.010) and associated positively with substrate diversity (Wald = 4.765, df = 1, p = 0.029).

*Orconectes immunis* was collected in the Kansas-Lower Republican and Missouri river basins; this species made up 1% (89 individuals) of the crayfishes sampled (Tables

1, 5). Females made up 37% of the individuals collected, and males and YOY comprised 34% and 29%, respectively. *Orconectes immunis* was collected at five sites within the Kansas-Lower Republican and Missouri river basins and was restricted to the northeast corner of the state (Figure 6). I sampled 71 sites within the expected range, resulting in a 7% capture frequency. The sample size of *O. immunis* was insufficient to quantify specific habitat associations.

Two species having historic distributions outside the study area were collected during this study (*Orconectes luteus* and *Procambarus simulans*). These species collectively made up 4% of all crayfish collected. *Orconectes luteus*, represented by 59 individuals, was collected in two third order streams (Washington and Ninemile creeks) in the Kansas-Lower Republican River Basin (Table 1, Figure 7). Encounters with this species were restricted to riffle and run macrohabitats, with no individuals collected in pools. The sample size of *O. luteus* was insufficient to quantify any habitat associations.

*Procambarus simulans*, represented by 368 individuals, was collected in two streams (Whites Creek and Beaver Creek) in the Kansas-Lower Republican River Basin (Figure 8). This species was the most abundant crayfish in Whites Creek and comprised 87% of all crayfish collected at this site. *Procambarus simulans* was only represented by one individual in Beaver Creek and was collected in a run macrohabitat. The sample size of *P. simulans* was insufficient to quantify any habitat associations.

One species (*Procambarus gracilis*) with a historical distribution in the Kansas-Lower Republican and Missouri river basins was not collected during this study (Table 1,

Figure 9). Sixty-eight sites were surveyed within this species historic distribution, with no individuals collected.

## Discussion

### *Cambarus*

*Cambarus diogenes* was the only member of this genus collected in this survey. This species is a semi-terrestrial burrowing crayfish known to occur in both lentic and lotic systems (Guiasu 2002; Pflieger 1996). Williams and Leonard (1952) collected this species at six sites throughout the Kansas-Lower Republican, Marias des Cygnes, and Missouri river basins (Figure 3B). I documented this species at 31 sites in the Missouri River Basin and the directly adjacent HUC 8 units in the Kansas-Lower Republican River Basin. This species was collected in a variety of habitats and stream sizes. *Cambarus diogenes* was associated negatively with run habitats, however these results need to be reviewed with caution due to the burrowing activity of this species. This species was sampled rarely in-stream (i.e., CRY-044-10) but burrows were associated to the closest macrohabitat. Considering the semi-terrestrial nature of the species, in-stream factors might be insufficient for predicting/detecting the presence of this species.

*Cambarus diogenes* prefer soils with high clay content within which they construct their burrows (Grow and Merchant 1980; Grow 1981). Clay soils have a high plasticity and the potential to hold various shapes when a force is applied. These characteristics make clay soils ideal for crayfish burrow construction. The preference for high clay content soils for burrow construction coupled with natural barriers (i.e., HUC 8)

could restrict this species to aquatic systems in the Missouri River Basin and the directly adjacent HUC 8 units in the Kansas-Lower Republican River Basin.

### *Orconectes*

*Orconectes* crayfishes, represented by 4 species (*O. immunis*, *O. luteus*, *O. neglectus*, and *O. virilis*), were the most abundant genus collected during this study. Collectively these species made up 93% (8,952 individuals) of crayfishes sampled and were collected in all HUC 8 units with exception of two, classified as devoid of water or were sampled but yielded no crayfish.

*Orconectes virilis* has an expected range throughout Kansas (Figure 4B). Williams and Leonard (1952) documented this species at 138 sites within all major river basins in Kansas. The current survey documented *O. virilis* at 97 sites within the Kansas-Lower Republican, Missouri, and Upper Republican river basins. The species was collected in all stream macrohabitats and stream sizes and was associated positively with pools and runs. These findings support Hamr (2002), stating this species occurs most often in streams with moderate flows and portions of streams with slower flow and mud or silt substrate.

*Orconectes virilis* was the most abundant species throughout the study area and collections were dominated by the YOY age class. The over abundance of YOY could be attributed to the life history of this species and sampling period. *Orconectes virilis* lay their eggs in late spring and YOY are produced in late May (Plieger 1996). Bovbjerg (1970) states juveniles of this species grow rapidly and account for the majority of the population by late summer. My observations were similar, with disproportionate

abundances of *O. virilis* sampled in late summer, specifically sites CRY-029-10 and CRY-039-10 (Table 2).

The dominance of *O. virilis* throughout the study site can be explained by their tolerance to abiotic factors and aggressive behavior. Temperature tolerance of crayfishes in the family Cambaridae is variable, but collectively they are more tolerant of high temperatures (Nystrom, 2002). Streams within the study area are subject to extreme summer conditions with temperatures exceeding 37 °C. However, harsh winter conditions with temperatures frequently dropping below 0 °C also occur. *Orconectes virilis* has exhibited a high tolerance for low temperatures in aquatic habitats. Unlike crayfishes that are more adept at burrowing (i.e., *Cambarus diogenes* and *O. immunis*) to survive winter conditions, *O. virilis* migrates to deeper water (Aiken 1967). This seasonal shift may exclude this species from peripheral habitats consisting of frozen water and substrate.

*Orconectes virilis* is an aggressive crayfish and occurs in densities up to 8.75 crayfish m<sup>-2</sup> (Hamr 2002). Bovbjerg (1970) documented aggressive behavior as causal in the competitive exclusion of *O. immunis* in stream habitats by *O. virilis*. High densities, aggressive behavior, and tolerance to extreme temperatures, coupled with low crayfish diversity appear to contribute to the dominance of this species in Kansas waterways.

*Orconectes neglectus* has an expected range throughout the southwestern portion of the Kansas-Lower Republican River Basin (Figure 5B). Williams and Leonard (1952) documented this species at nine sites in Riley and Wabaunsee Counties. Subsequently, Minckley and Deacon (1959) documented this species in western Pottawatomie County

and one stream (Mission Creek) in Marshall County. The current survey documented this species at 18 sites in the Kansas-Lower Republican and Upper Republican river basins.

Williams and Leonard (1952) described *O. neglectus* as inhabiting streams with swift flow and rocky substrates. This study suggests *O. neglectus* is associated with diverse substrates and shallow depths. These factors are characteristic of permanent streams with high flow and low turbidity, as described above. Many streams surveyed in the Flint Hills of Kansas exhibit these characteristics, and *O. neglectus* was abundant in these habitats.

The current survey documented the first specimens from tributaries to the Little Blue River southeast of Hanover in Washington County (Knedlik and Cottonwood creeks). Metcalf and Distler (1961) collected this species in Nebraska, however these specimens are the first documentation in Kansas. These specimens were restricted to small tributaries of the Little Blue River with diverse substrates and a maximum depth of 0.5 m. Chelae of this species were collected at Washington State Fishing Lake, suggesting populations might be established further west in this basin, however no live specimens were collected from this impoundment.

This species also was collected in the Upper Republican River Basin at four sites, which were characterized as spring-fed streams with perennial flows. No specimens have been collected from this western-most portion of the basin since 1900, and populations in the Upper Republican River Basin were thought to be restricted to Rock Creek in Dundee County, Nebraska (Metcalf and Distler 1961). Contrary to previous habitat associations, populations in the Upper Republican inhabit streams dominated by

sand and fine substrates. Metcalf and Distler (1961) observations support these findings and suggest this species is tolerant of shallow streams with sand substrates in the Upper Republican River basin, but restricted to cool, clear, unpolluted streams.

*Orconectes virilis* was present at 16 of the 18 sites where I collected *O. neglectus*. The co-occurrence of these two species could be explained by microhabitat partitioning. As mentioned above, *O. virilis* is an aggressive crayfish that commonly occurs in pools and runs, specifically habitats with increased depth and moderate to low flow. Pflieger (1996) suggests *O. neglectus* occurs in rocky riffles and shallow pools. While this study did not suggest macrohabitat separation for *O. neglectus*, the explained association with diverse substrates and shallow depths is characteristic of rocky riffles and shallow pools. While competition between these two species could be present, this spatial separation might reduce these species interactions.

*Orconectes immunis* had an expected range throughout the northeastern portion of the state (Figure 6B) and I collected individuals at five sites in the Kansas-Lower Republican and Missouri river basins. All individuals were collected in stagnant streams with minimal flow. The low capture rate of this species might be explained by competitive exclusion by *O. virilis*. Bovbjerg (1970) documented aggressive behavior as a mechanism of competitive exclusion of *O. immunis* by *Orconectes virilis*. The aggressive behavior and ubiquitous distribution of *O. virilis* could limit populations of *O. immunis* to more marginal habitats, characterized by low levels of dissolved oxygen and summer drying.



*Orconectes luteus* had an expected range throughout the Marais des Cygnes River Basin and adjacent streams in the Kansas-Lower Republican River Basin (Figure 7B). Williams and Leonard (1952) documented this species at five sites within the Marais des Cygnes River Basin. Subsequently, Metcalf and Distler (1961) collected this species at two streams in the Kansas-Lower Republican River Basin directly adjacent to the Marais des Cygnes River Basin. I collected this species at two sites, and only from run and riffle macrohabitats.

*Orconectes luteus* inhabits streams with permanent flow and diverse substrate composition (Muck et. al. 2002). My survey data did not allow delineation of any habitat associations, due to low capture rate, but stream habitats where this species was collected were consistent with those reported by Muck et al. (2002). Washington and Ninemile Creeks are both third order streams with permanent flow. Macrohabitats where this species was present (riffle and run) had diverse substrates but were dominated by fine to coarse gravel. This species is similar to *O. neglectus* in both appearance and ecology but the two species have never been known to co-occur (Pflieger 1996; Muck et. al. 2002; DiStefano et. al. 2003). Both species are currently present in the Kansas-Lower Republican River Basin but are still separated by one HUC 8 unit (Figures 5A and 7A).

#### *Procambarus*

*Procambarus simulans* had an expected range throughout the Arkansas, Smoky Hill-Saline, and Solomon river basins (Figure 8B); this area was not included in this survey. Williams and Leonard (1952) collected this species in ponds and ditches but rarely in streams. The current study documented *P. simulans* at two sites in the Kansas-

Lower Republican River Basin. This species was the most abundant crayfish sampled from Beaver Creek (368 individuals). To better understand the status of this species in Kansas more surveys need to be conducted within and outside its expected range.

*Procambarus gracilis* had an expected range throughout the Neosho, Verdigris, Kansas-Lower Republican, and Missouri river basins but was not collected during this survey (Figures 9). *Procambarus gracilis* is a burrowing crayfish that typically inhabits wet meadows, ditches, and ephemeral ponds and is rarely collected in streams (Williams and Leonard 1952; Hobbs III and Rewolinski 1985; Pflieger 1996). The absence of this species is likely explained by the concentrated efforts on lotic systems and this species' affinity for ephemeral lentic systems.

## Conclusions

Isolating effects of changes in pre- and post-Pleistocene river drainages have been the impetus for crayfish diversity in North America (Taylor et. al. 1996; Taylor et. al. 2007). Kansas represents the western most edge of this diversity. Six species were collected during my study with new distributional records for four species (*Cambarus diogenes*, *Orconectes luteus*, *O. neglectus*, and *Procambarus simulans*). *Orconectes luteus* was present in southeast most portion of the Kansas-Lower Republican River Basin but does not co-occur with *O. neglectus*. *Orconectes neglectus* is present throughout the Kansas-Lower Republican River Basin but restricted to less turbid streams with moderate flow and diverse substrates. Additionally, populations of this species were present in the Upper Republican River Basin but restricted to the South Fork Republican

River and small tributaries that support perennial flow. *Procambarus simulans* was present in the western portion of the Kansas-Lower Republican River Basin.

Future surveys in the Kansas-Lower Republican, Missouri, and Upper Republican river basins will add to the growing knowledge of crayfish communities in Kansas. The exclusion of lentic habitats in my study restricted the ability to effectively survey species adapted to these environments (i.e., *Orconectes immunis* and *Procambarus gracilis*).

Crayfish have been an understudied fauna in Kansas and concentrated survey efforts towards these taxa need to be initiated to understand the conservation status of these species. Qualitative and quantitative surveys of lentic and lotic systems, including burrow excavation, are critical to assess crayfish communities. These efforts need to be directed first towards river basins with known historical crayfish diversity (i.e., Marias des Cygnes, Neosho, Spring, and Verdigris river basins). Once current distributions of crayfishes have been established, population and ecological parameters need to be assessed to determine the conservation status of these species.

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Table 1. Summary table: Total number of individuals collected and habitat associations, by species in Kansas-Lower Republican, Missouri, and Upper Republican river basins. \*Total number of individuals collected and burrows observed.

<b>Species</b>	<b>Individuals Collected</b>	<b># of Sites Collected in Kansas-Lower Republican</b>	<b># of Sites Collected in Missouri</b>	<b># of Sites Collected in Upper Republican</b>	<b>Sites of Occurrence</b>	<b>Habitat Associations</b>
<i>Cambarus diogenes</i>	287*	9	22	0	31	Associated negatively with run macrohabitat
<i>Orconectes immunis</i>	89	3	2	0	5	-
<i>Orconectes luteus</i>	59	2	0	0	2	-
<i>Orconectes neglectus</i>	1,254	14	0	4	18	Diverse substrates shallow depth
<i>Orconectes virilis</i>	7,550	64	24	9	97	Pool and run macrohabitats
<i>Procambarus simulans</i>	368	2	0	0	2	-
<b>Total</b>	<b>9,607</b>					

Table 2. *Cambarus diogenes*: Sites and number of males, females, young-of-year (YOY), and burrows observed.

<b>Site</b>	<b>Stream</b>	<b>Basin</b>	<b>Female</b>	<b>Male</b>	<b>YOY</b>	<b>Burrows</b>
CRY-001-09	Wolf Creek	Missouri	0	1	0	0
CRY-020-09	Nebo Creek	Kansas-Lower Republican	1	3	0	0
CRY-021-09	Buckhorn Creek	Kansas-Lower Republican	0	0	0	13
CRY-022-09	Honey Creek	Kansas-Lower Republican	0	2	0	6
CRY-040-10	Delaware River	Kansas-Lower Republican	0	1	0	2
CRY-042-10	Trib. to Wolfley Creek	Kansas-Lower Republican	0	1	0	3
CRY-044-10	Duck Creek	Kansas-Lower Republican	1	1	0	7
CRY-049-10	Trib. to Camp Creek	Kansas-Lower Republican	0	0	3	4
CRY-050-10	Crooked Creek	Kansas-Lower Republican	1	0	3	0
CRY-074-11	S. Fork Nemaha River	Missouri	1	1	0	0
CRY-075-11	Negro Creek	Missouri	1	0	0	0
CRY-077-11	Tennessee Creek	Missouri	0	1	0	2
CRY-080-11	Trib. to Deer Creek	Missouri	0	1	0	0
CRY-081-11	Rock Creek	Missouri	1	0	0	2
CRY-082-11	Trib. to Pony Creek	Missouri	2	2	0	32
CRY-083-11	Spring Creek	Missouri	2	1	0	7
CRY-084-11	Terrapin Creek	Missouri	1	0	0	39
CRY-085-11	Spring Branch	Missouri	1	1	2	33
CRY-086-11	Noharts Creek	Missouri	0	0	0	12
CRY-087-11	Trib. to Pony Creek	Missouri	1	1	1	11
CRY-089-11	Mill Creek	Missouri	0	1	0	4
CRY-090-11	Mission Creek	Missouri	1	0	0	9

Table 2. (continued)

<b>Site</b>	<b>Stream</b>	<b>Basin</b>	<b>Female</b>	<b>Male</b>	<b>YOY</b>	<b>Burrows</b>
CRY-091-11	Charlie Creek	Missouri	0	0	0	1
CRY-093-11	Clear Creek	Kansas-Lower Republican	0	0	0	3
CRY-120-11	Little Plum Creek	Missouri	0	2	1	2
CRY-121-11	Brewery Creek	Missouri	0	2	0	21
CRY-123-11	Coon Creek	Missouri	1	1	0	2
CRY-126-11	Peters Creek	Missouri	0	0	0	1
CRY-127-11	Ryans Branch	Missouri	2	0	0	13
CRY-128-11	Cedar Creek	Missouri	2	0	0	4
CRY-129-11	Trib. to Buttermilk Creek	Missouri	0	0	0	2

Table 3. *Orconectes virilis*: Sites and number of males, females, and young-of-year (YOY) collected.

<b>Site</b>	<b>Stream</b>	<b>Basin</b>	<b>Female</b>	<b>Male</b>	<b>YOY</b>
CRY-002-09	Rock Creek	Missouri	2	1	1
CRY-003-09	Trib. to Euchre Creek	Missouri	6	11	0
CRY-004-09	Pony Creek	Missouri	45	46	0
CRY-005-09	Trib. To Deer Creek	Missouri	24	25	0
CRY-009-09	S. Fork Republican River	Upper Republican	21	16	0
CRY-010-09	S. Fork Republican River	Upper Republican	15	6	1
CRY-013-09	Mission Creek	Kansas-Lower Republican	39	14	1
CRY-014-09	Elm Creek	Kansas-Lower Republican	56	57	21
CRY-015-09	Spring Creek	Kansas-Lower Republican	3	2	2
CRY-016-09	Hise Creek	Kansas-Lower Republican	114	111	48
CRY-017-09	Lost Creek	Kansas-Lower Republican	83	81	21
CRY-018-09	Halfday Creek	Kansas-Lower Republican	13	19	44
CRY-019-09	Negro Creek	Kansas-Lower Republican	5	3	7
CRY-020-09	Nebo Creek	Kansas-Lower Republican	43	64	25
CRY-021-09	Buckhorn Creek	Kansas-Lower Republican	12	14	3
CRY-022-09	Honey Creek	Kansas-Lower Republican	56	36	2
CRY-023-09	Washington Creek	Kansas-Lower Republican	369	302	81
CRY-024-09	Camp Creek	Kansas-Lower Republican	30	33	0
CRY-025-09	Beaver Creek	Kansas-Lower Republican	94	82	0
CRY-026-10	Whites Creek	Kansas-Lower Republican	23	20	0
CRY-027-10	Beaver Creek	Kansas-Lower Republican	16	5	0
CRY-029-10	Trib. To Republican River	Kansas-Lower Republican	49	17	276
CRY-030-10	Elm Creek	Kansas-Lower Republican	20	4	23
CRY-032-10	Mountain Creek	Kansas-Lower Republican	12	2	50
CRY-033-10	Snipe Creek	Kansas-Lower Republican	2	1	54
CRY-034-10	Weyer Creek	Kansas-Lower Republican	11	5	7
CRY-035-10	Walnut Creek	Kansas-Lower Republican	17	18	11
CRY-036-10	Deadmans Creek	Kansas-Lower Republican	35	21	63
CRY-037-10	Dixon Creek	Kansas-Lower Republican	9	15	51
CRY-038-10	Plum Creek	Upper Republican	6	0	0
CRY-039-10	Little Beaver Creek	Upper Republican	139	128	869
CRY-040-10	Delaware River	Kansas-Lower Republican	107	105	63
CRY-041-10	Craigs Creek	Kansas-Lower Republican	10	10	2
CRY-042-10	Trib. to Wolfley Creek	Kansas-Lower Republican	9	14	19
CRY-043-10	N. Cedar Creek	Kansas-Lower Republican	39	44	40
CRY-044-10	Duck Creek	Kansas-Lower Republican	50	41	21
CRY-045-10	Wakarusa River	Kansas-Lower Republican	23	27	88
CRY-046-10	Lynn Creek	Kansas-Lower Republican	35	39	2
CRY-047-10	Ninemile Creek	Kansas-Lower Republican	20	29	7
CRY-048-10	Hog Creek	Kansas-Lower Republican	36	30	11
CRY-049-10	Trib. to Camp Creek	Kansas-Lower Republican	11	13	11
CRY-050-10	Crooked Creek	Kansas-Lower Republican	13	11	0

Table 3. (continued)

<b>Site</b>	<b>Stream</b>	<b>Basin</b>	<b>Female</b>	<b>Male</b>	<b>YOY</b>
CRY-051-10	Ninemile Creek	Missouri	7	6	3
CRY-052-10	Pleasant Creek	Kansas-Lower Republican	97	83	1
CRY-053-10	Rock Creek	Kansas-Lower Republican	32	29	42
CRY-054-10	Soldier Creek	Kansas-Lower Republican	8	10	2
CRY-055-10	Trib. To Mission Creek	Kansas-Lower Republican	35	52	15
CRY-058-11	Prairie Dog Creek	Upper Republican	6	6	3
CRY-059-11	Sappa Creek	Upper Republican	1	0	0
CRY-063-11	N. Fork Beaver Creek	Upper Republican	3	2	3
CRY-064-11	N. Fork Beaver Creek	Upper Republican	2	1	0
CRY-065-11	Trib. to Beaver Creek	Upper Republican	3	3	0
CRY-066-11	Kings Creek	Kansas-Lower Republican	3	4	5
CRY-067-11	Wildcat Creek	Kansas-Lower Republican	12	7	0
CRY-068-11	Clarks Creek	Kansas-Lower Republican	3	12	10
CRY-069-11	Trib. to Clarks Creek	Kansas-Lower Republican	1	3	0
CRY-070-11	Mulberry Creek	Kansas-Lower Republican	23	21	59
CRY-071-11	W. Branch Mill Creek	Kansas-Lower Republican	1	0	0
CRY-072-11	Spring Creek	Kansas-Lower Republican	0	1	0
CRY-075-11	Negro Creek	Missouri	0	0	4
CRY-077-11	Tennessee Creek	Missouri	22	17	0
CRY-078-11	Fisher Creek	Missouri	0	0	1
CRY-080-11	Trib. to Deer Creek	Missouri	1	1	0
CRY-082-11	Trib. to Pony Creek	Missouri	22	19	0
CRY-083-11	Spring Creek	Missouri	16	18	5
CRY-084-11	Terrapin Creek	Missouri	26	15	0
CRY-086-11	Noharts Creek	Missouri	4	1	1
CRY-087-11	Trib. to Pony Creek	Missouri	39	35	0
CRY-090-11	Mission Creek	Missouri	1	2	3
CRY-091-11	Charlie Creek	Missouri	1	0	1
CRY-092-11	S. Fork Wolf River	Missouri	1	1	2
CRY-093-11	Clear Creek	Kansas-Lower Republican	1	0	13
CRY-094-11	Swede Creek	Kansas-Lower Republican	10	7	3
CRY-095-11	Humboldt Creek	Kansas-Lower Republican	3	1	38
CRY-096-11	Silver Creek	Kansas-Lower Republican	0	2	0
CRY-097-11	Wildcat Creek	Kansas-Lower Republican	2	0	0
CRY-098-11	Spring Creek	Kansas-Lower Republican	5	3	0
CRY-100-11	Trib. to East Creek	Kansas-Lower Republican	7	6	2
CRY-101-11	Walnut Creek	Kansas-Lower Republican	1	0	1
CRY-103-11	Trib. to White Rock Creek	Kansas-Lower Republican	12	1	0
CRY-104-11	Spring Creek	Kansas-Lower Republican	4	1	110
CRY-105-11	Big Timber Creek	Kansas-Lower Republican	15	4	134
CRY-107-11	Spring Creek	Kansas-Lower Republican	5	0	101
CRY-109-11	Dry Creek	Kansas-Lower Republican	1	2	118

Table 3. (continued)

<b>Site</b>	<b>Stream</b>	<b>Basin</b>	<b>Female</b>	<b>Male</b>	<b>YOY</b>
CRY-111-11	Riddle Creek	Kansas-Lower Republican	6	2	0
CRY-112-11	Rose Creek	Kansas-Lower Republican	3	3	30
CRY-113-11	Cherry Creek	Kansas-Lower Republican	0	0	19
CRY-114-11	Trib. to Mill Creek	Kansas-Lower Republican	1	2	30
CRY-116-11	Camp Creek	Kansas-Lower Republican	1	0	0
CRY-117-11	Cottonwood Creek	Kansas-Lower Republican	14	8	128
CRY-119-11	Salt Creek	Missouri	26	16	42
CRY-120-11	Little Plum Creek	Missouri	31	40	250
CRY-121-11	Brewery Creek	Missouri	1	0	8
CRY-122-11	Little Walnut Creek	Missouri	10	24	28
CRY-126-11	Peters Creek	Missouri	1	4	14
CRY-127-11	Ryans Branch	Missouri	20	42	84
CRY-129-11	Trib. to Buttermilk Creek	Missouri	0	1	0

Table 4. *Orconectes neglectus*: Sites and number of males, females, and young-of-year (YOY) collected.

<b>Site</b>	<b>Stream</b>	<b>Basin</b>	<b>Female</b>	<b>Male</b>	<b>YOY</b>
CRY-009-09	S. Fork Republican River	Upper Republican	5	7	20
CRY-010-09	S. Fork Republican River	Upper Republican	2	0	0
CRY-013-09	Mission Creek	Kansas-Lower Republican	22	14	2
CRY-014-09	Elm Creek	Kansas-Lower Republican	92	117	218
CRY-015-09	Spring Creek	Kansas-Lower Republican	96	118	60
CRY-025-09	Beaver Creek	Upper Republican	20	25	0
CRY-031-10	Trib. to Hop Creek	Kansas-Lower Republican	2	5	6
CRY-032-10	Mountain Creek	Kansas-Lower Republican	4	4	0
CRY-035-10	Walnut Creek	Kansas-Lower Republican	51	20	1
CRY-053-10	Rock Creek	Kansas-Lower Republican	13	7	3
CRY-054-10	Soldier Creek	Kansas-Lower Republican	6	4	0
CRY-064-11	N. Fork Beaver Creek	Upper Republican	2	3	2
CRY-066-11	Kings Creek	Kansas-Lower Republican	22	21	28
CRY-071-11	W. Branch Mill Creek	Kansas-Lower Republican	2	7	1
CRY-072-11	Spring Creek	Kansas-Lower Republican	13	6	7
CRY-094-11	Swede Creek	Kansas-Lower Republican	87	84	8
CRY-115-11	Knedlik Creek	Kansas-Lower Republican	2	0	4
CRY-117-11	Cottonwood Creek	Kansas-Lower Republican	2	1	8

Table 5. *Orconectes immunis*: Sites and number of males, females, and young-of-year (YOY) collected.

<b>Site</b>	<b>Stream</b>	<b>Basin</b>	<b>Female</b>	<b>Male</b>	<b>YOY</b>
CRY-022-09	Honey Creek	Kansas-Lower Republican	11	12	2
CRY-034-10	Weyer Creek	Kansas-Lower Republican	13	12	24
CRY-040-10	Delaware River	Kansas-Lower Republican	1	0	0
CRY-077-11	Tennessee Creek	Missouri	7	5	0
CRY-128-11	Cedar Creek	Missouri	1	1	0



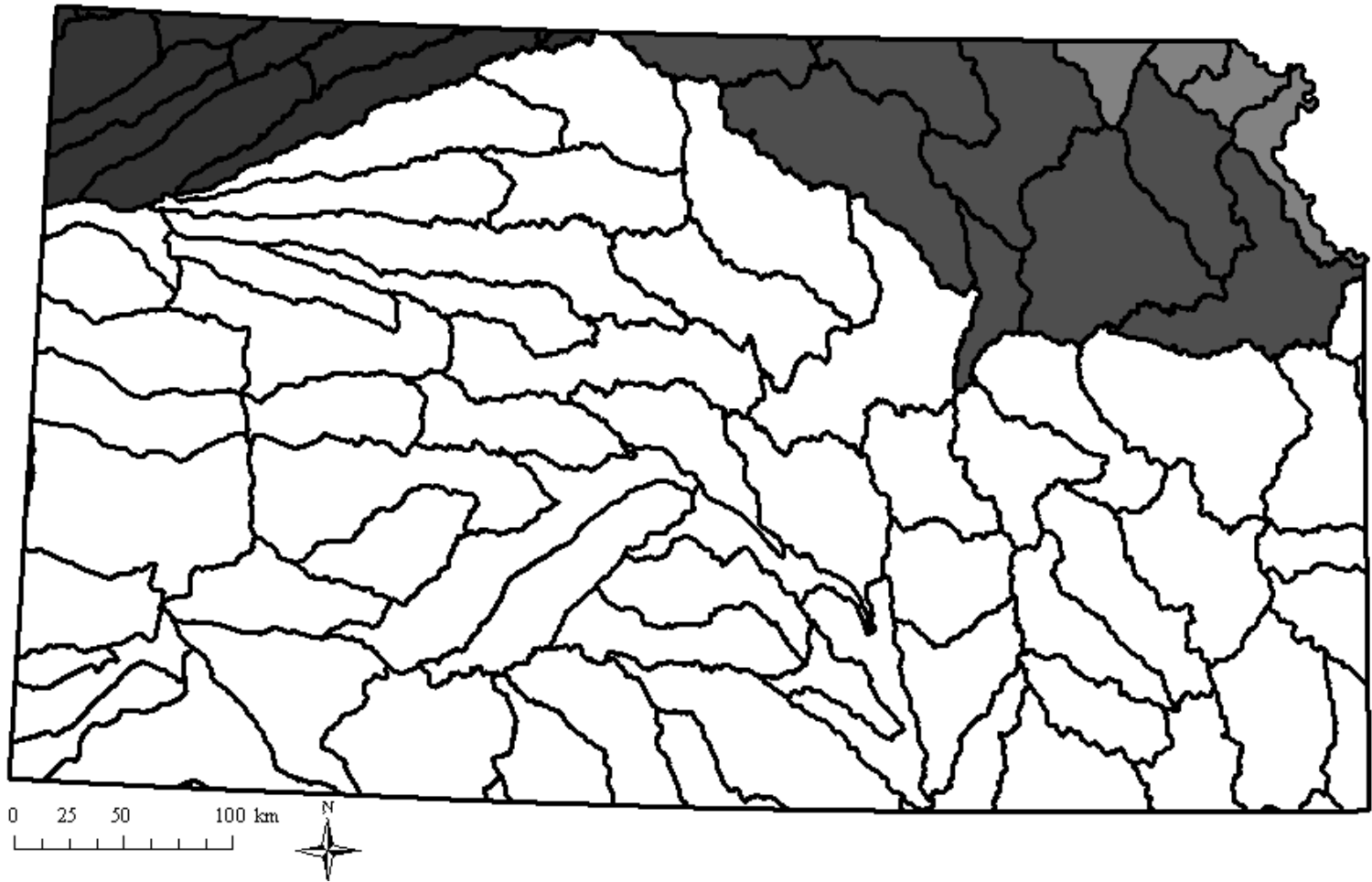


Figure 1. Map of survey area stratified by Hydrological Unit Code 8 watersheds. The Upper Republican River Basin indicated in dark gray, Kansas-Lower Republican River Basin indicated in gray, and the Missouri River Basin indicated in light gray.

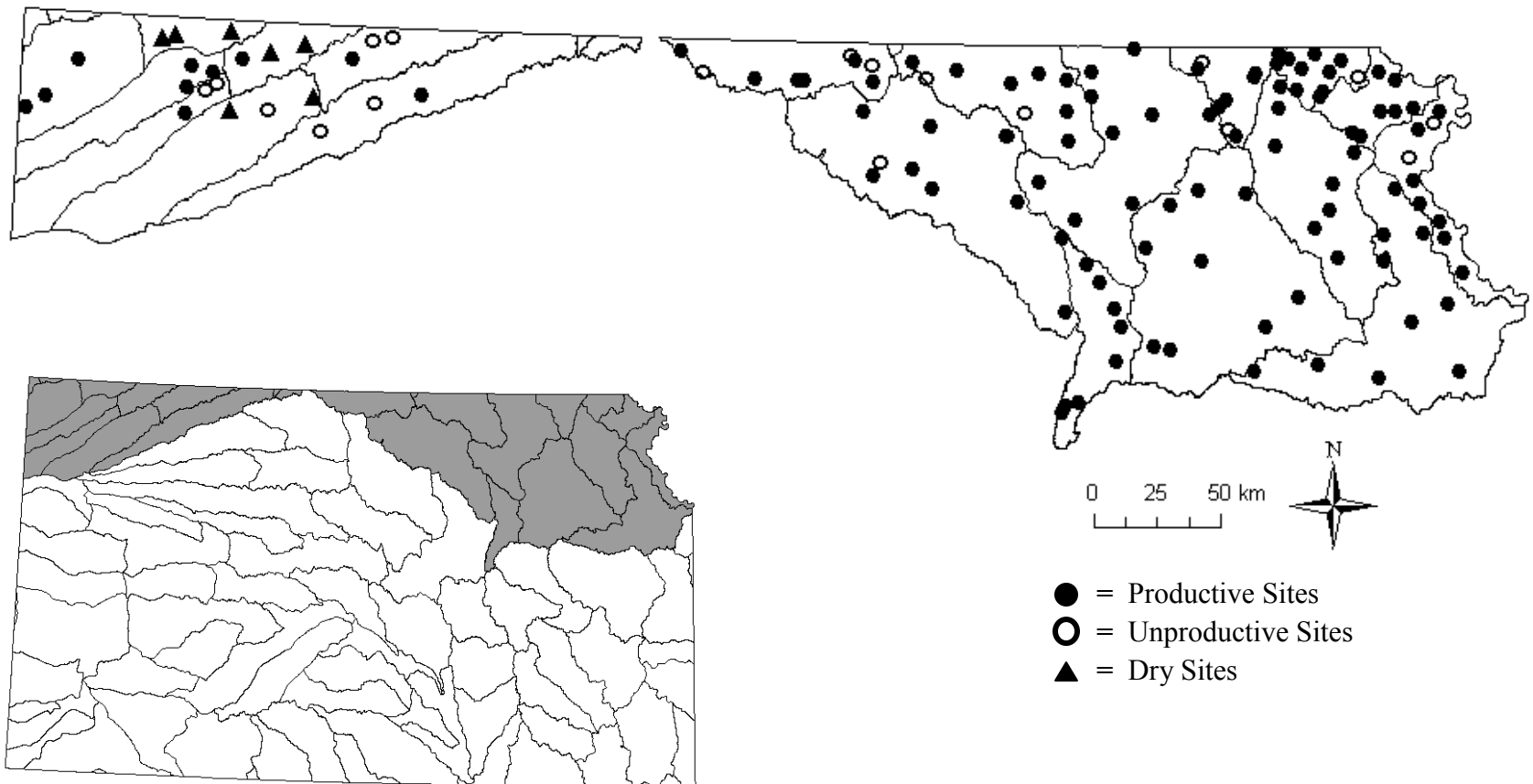


Figure 2. Map of sites surveyed in the Kansas-Lower Republican, Missouri, and Upper Republican river basins.

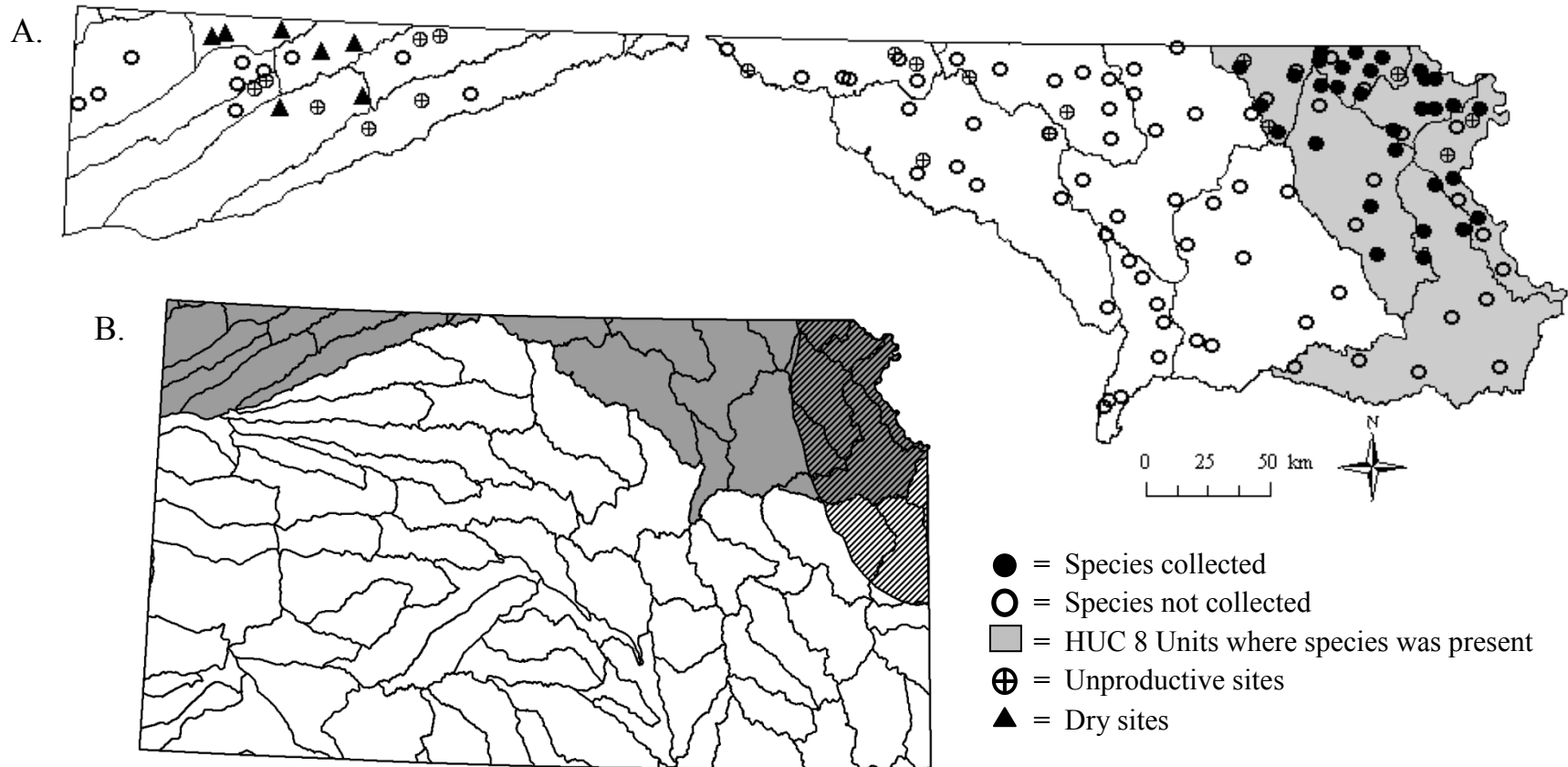


Figure 3. *Cambarus diogenes*: **A.** Map of sites where this species was surveyed. **B.** Map of survey area indicated in gray. Historical distribution of this species is indicated by black cross-hatch (Williams and Leonard 1952).

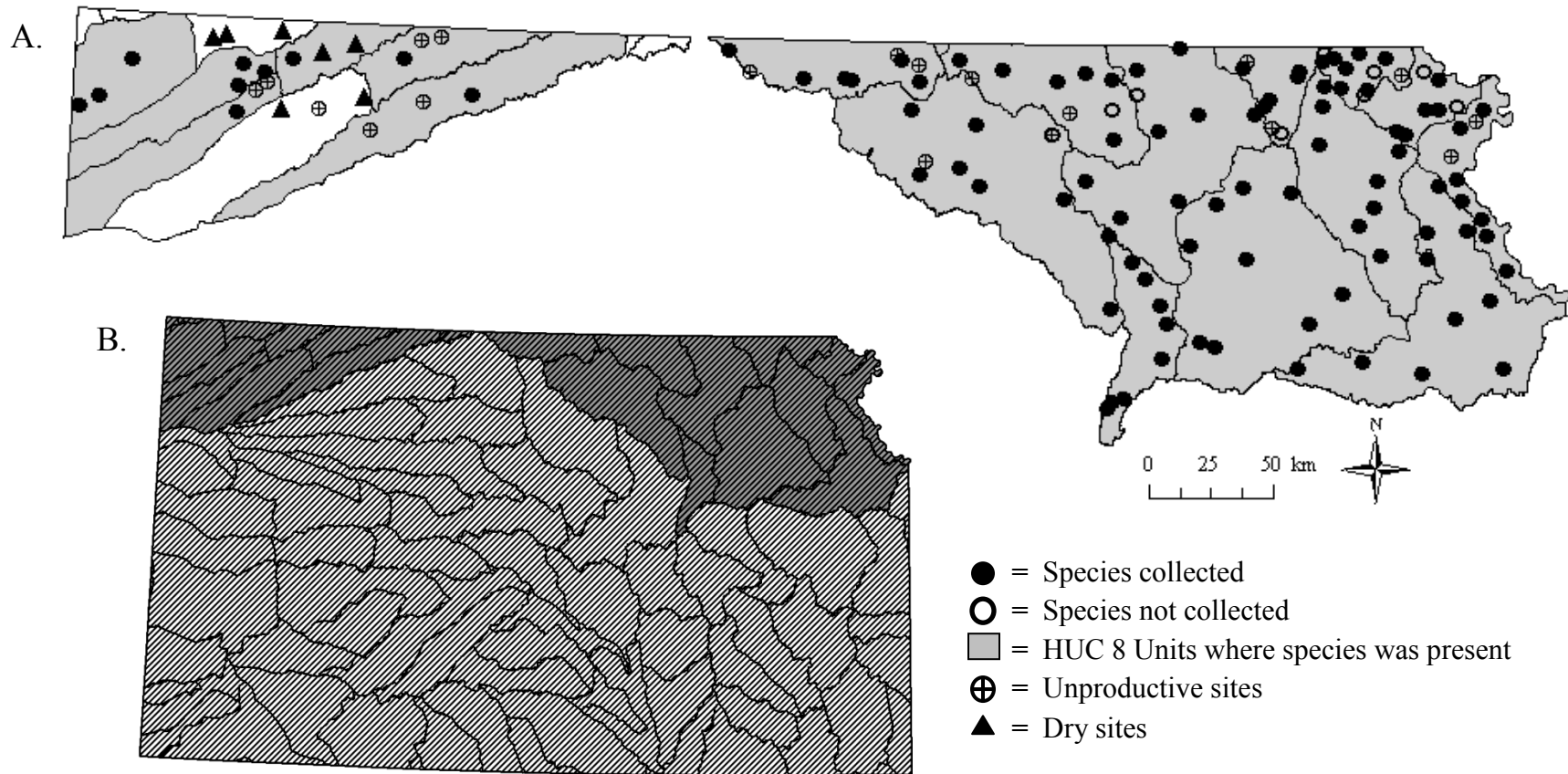


Figure 4. *Orconectes virilis*: **A.** Map of sites where this species was surveyed. **B.** Map of survey area indicated in gray. Historical distribution of this species is indicated by black cross-hatch (Williams and Leonard 1952).

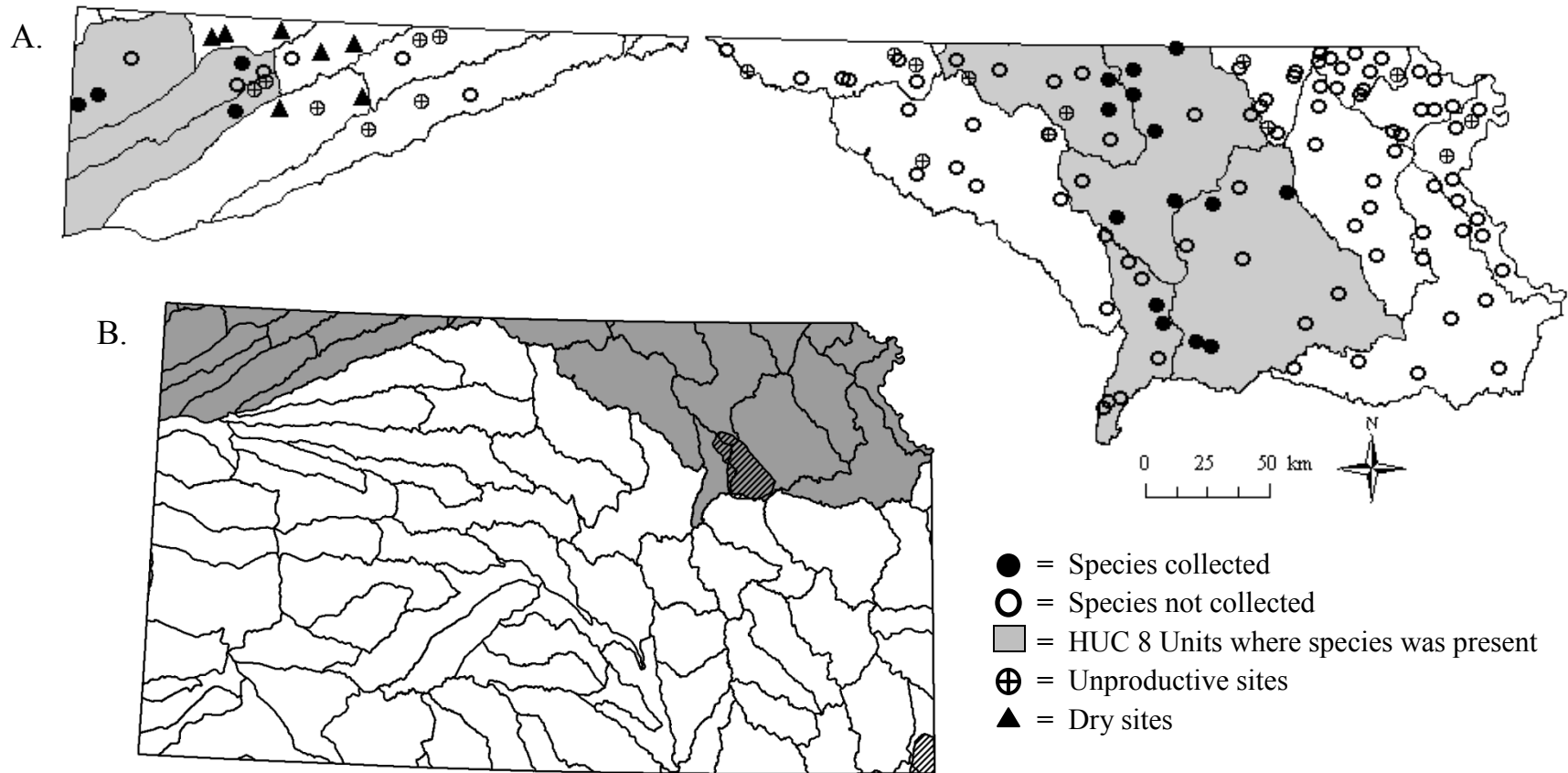


Figure 5. *Orconectes neglectus*: **A.** Map of sites where this species was surveyed. **B.** Map of survey area indicated in gray. Historical distribution of this species is indicated by black cross-hatch (Williams and Leonard 1952).

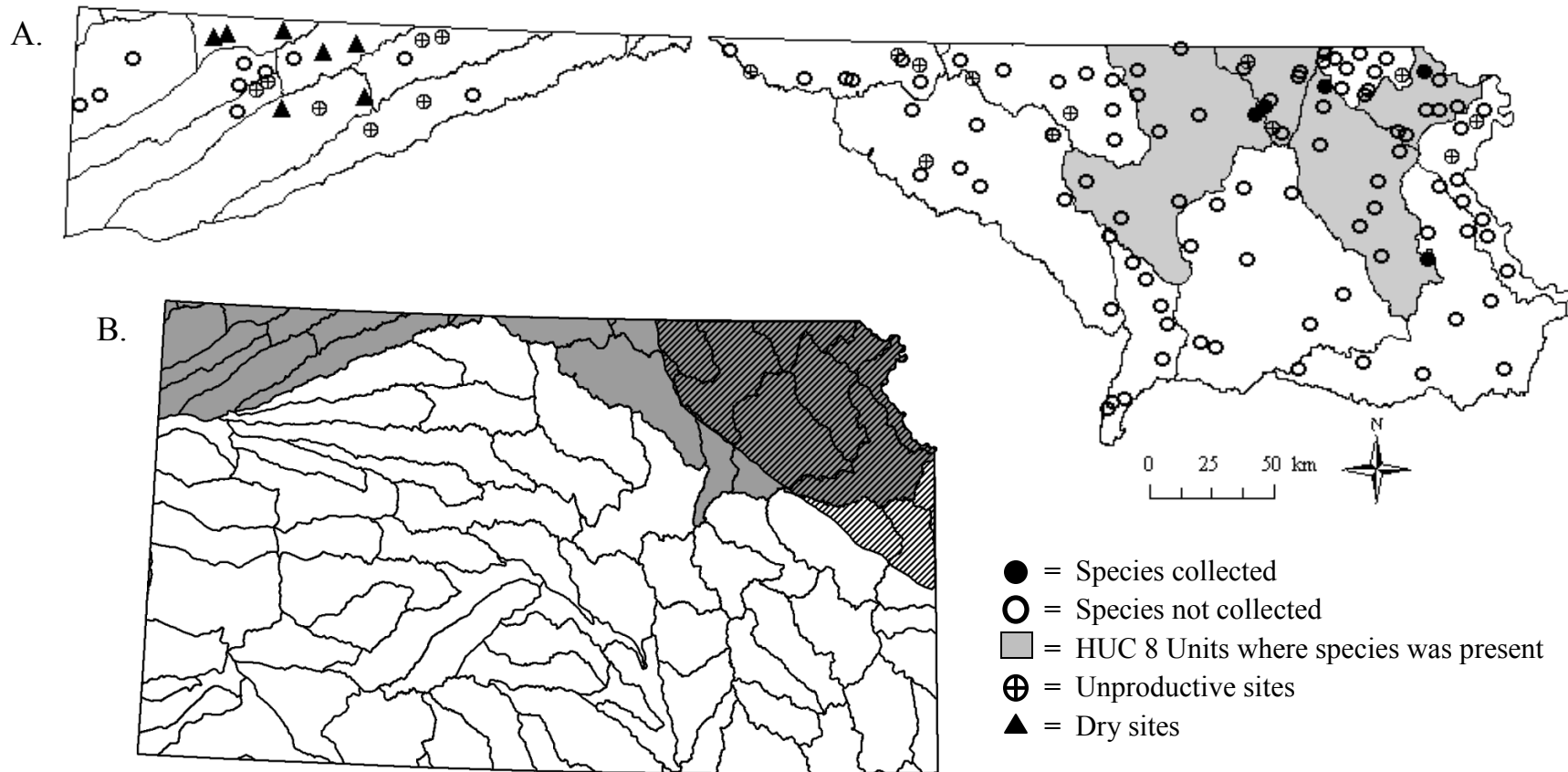


Figure 6. *Orconectes immunis*: **A.** Map of sites where this species was surveyed. **B.** Map of survey area indicated in gray. Historical distribution of this species is indicated by black cross-hatch (Williams and Leonard 1952).

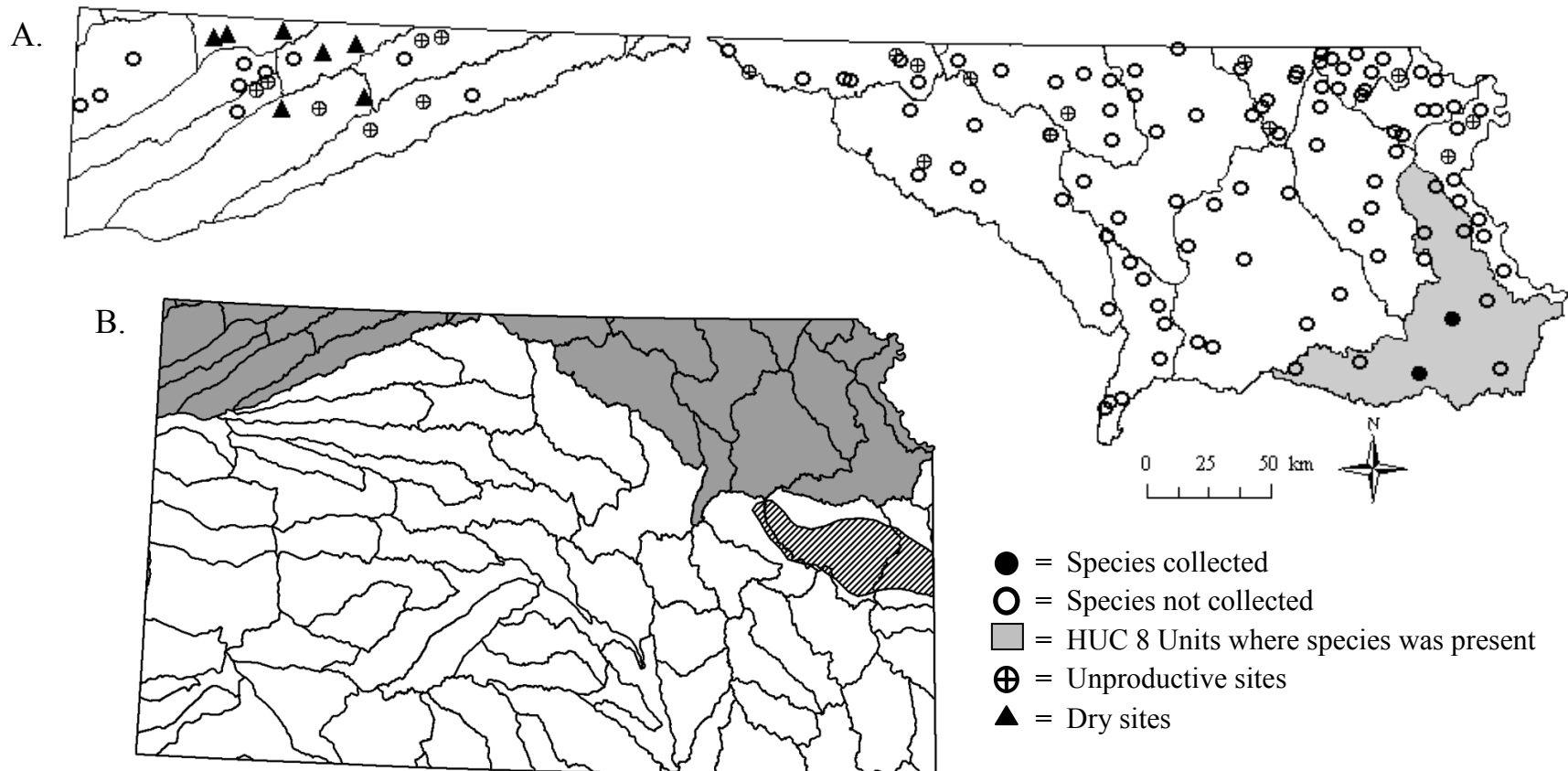


Figure 7. *Orconectes luteus*: **A.** Map of sites where this species was surveyed. **B.** Map of survey area indicated in gray. Historical distribution of this species is indicated by black cross-hatch (Williams and Leonard 1952).

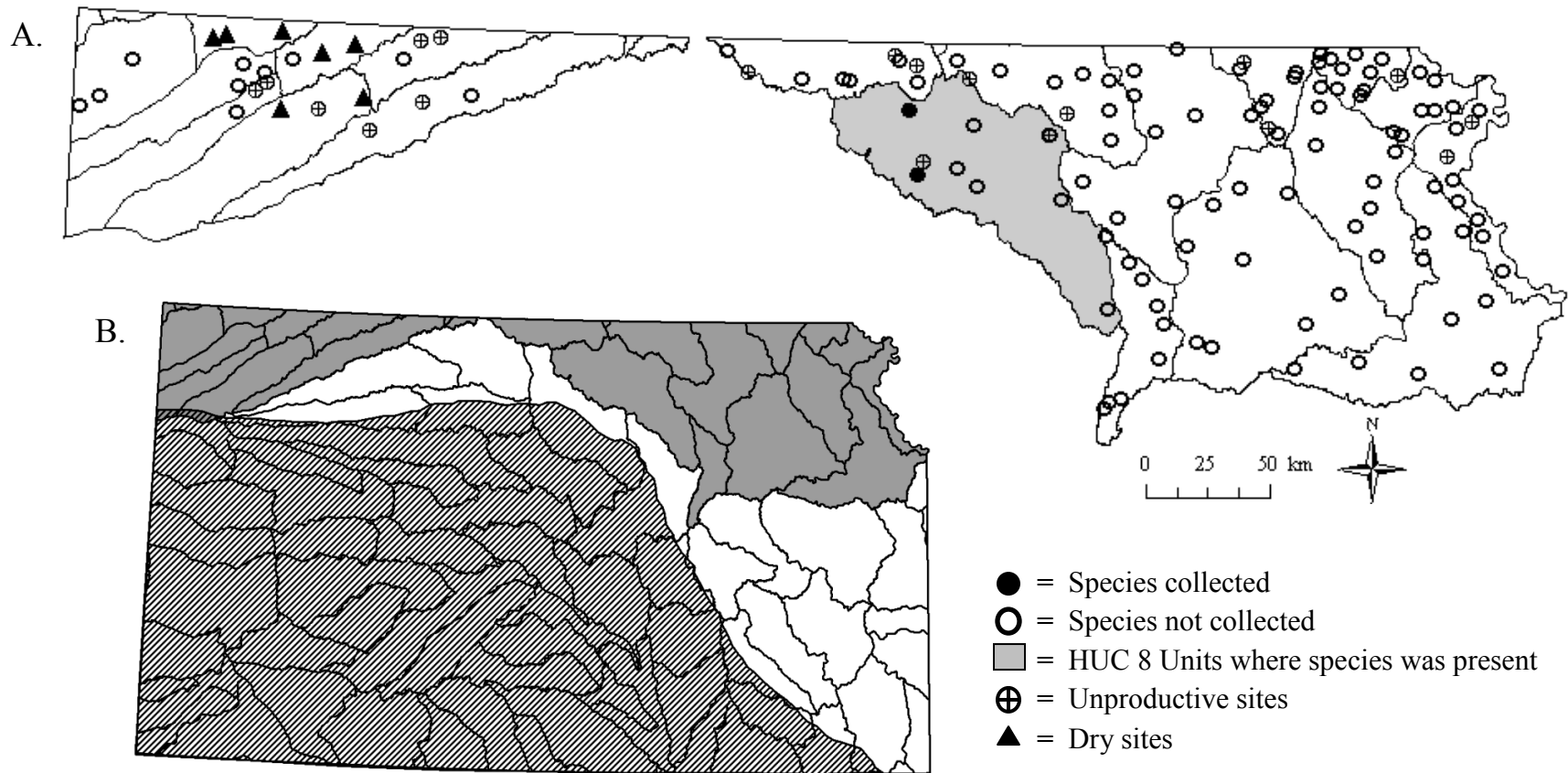


Figure 8. *Procambarus simulans*: **A.** Map of sites where this species was surveyed. **B.** Map of survey area indicated in gray. Historical distribution of this species is indicated by black cross-hatch (Williams and Leonard 1952).



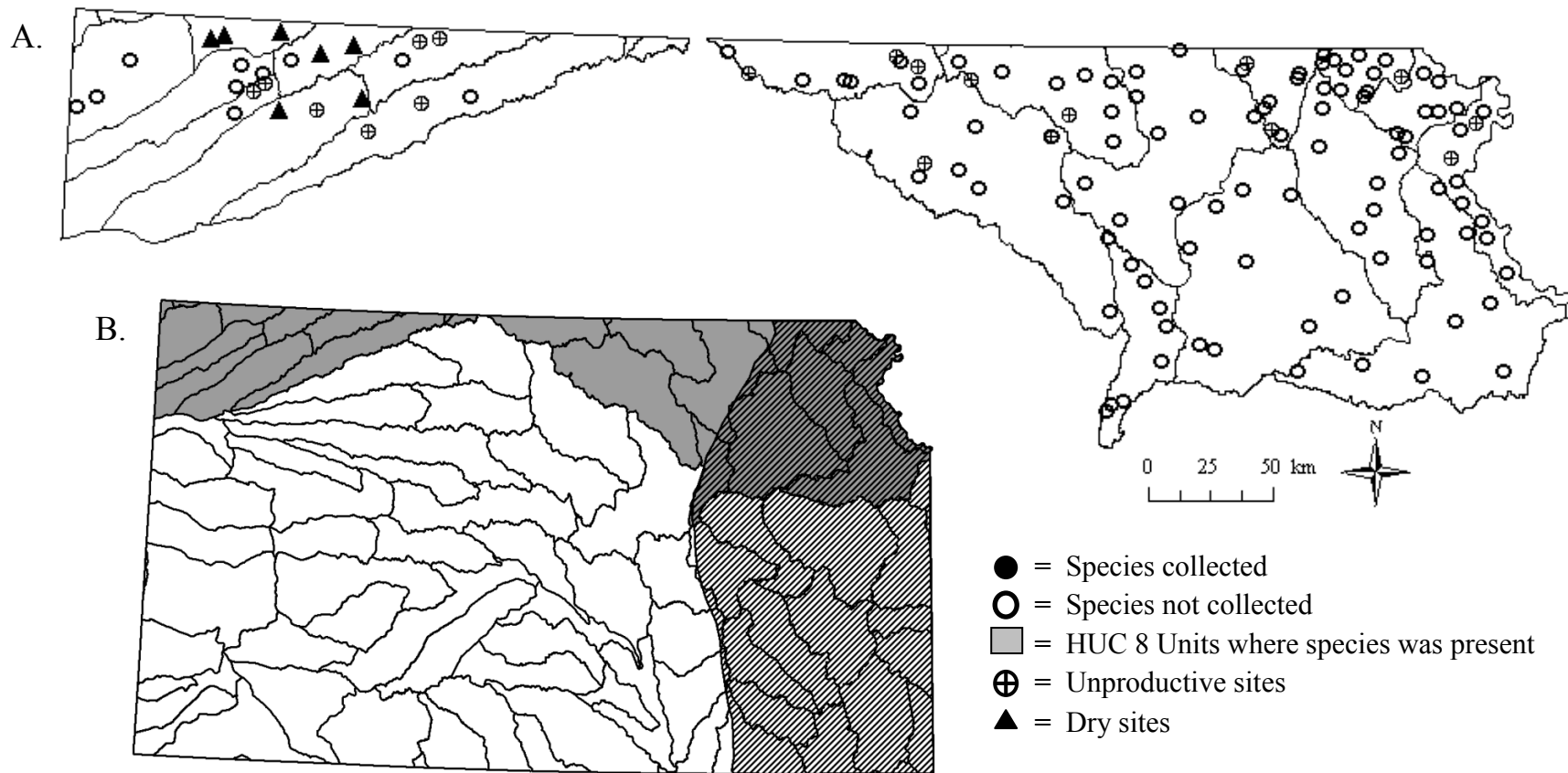


Figure 9. *Procambarus gracilis*: **A.** Map of sites where this species was surveyed. **B.** Map of survey area indicated in gray. Historical distribution of this species is indicated by black cross-hatch (Williams and Leonard 1952).

Appendix A: Survey site descriptions

<b>Site</b>	<b>Date</b>	<b>County</b>	<b>Stream</b>	<b>Order</b>	<b>Drainage Basin</b>	<b>HUC 8</b>	<b>Lat.</b>	<b>Long.</b>
CRY-001-09	6/1/2009	Brown	Wolf Creek	2	Missouri	10240005	39.835100	-95.601583
CRY-002-09	6/3/2009	Doniphan	Rock Creek	3	Missouri	10240011	39.719767	-95.115767
CRY-003-09	6/5/2009	Brown	Trib. to Euchre Creek	1	Missouri	10240008	39.848933	-95.582317
CRY-004-09	6/6/2009	Brown	Pony Creek	3	Missouri	10240008	39.961450	-95.751017
CRY-005-09	6/16/2009	Nemaha	Trib. To Deer Creek	2	Missouri	10240007	39.913500	-95.919033
CRY-009-09	6/30/2009	Cheyenne	S. Fork Republican River	3	Upper Republican	10250003	39.710683	-101.918600
CRY-010-09	7/1/2009	Cheyenne	S. Fork Republican River	2	Upper Republican	10250003	39.671783	-102.013333
CRY-011-09	7/1/2009	Rawlins	Beaver Creek	2	Upper Republican	10250012	39.760050	-101.130517
CRY-012-09	7/2/2009	Rawlins	Beaver Creek	3	Upper Republican	10250012	39.787117	-101.074300
CRY-013-09	7/10/2009	Marshall	Mission Creek	3	Kansas-Lower Republican	10270205	39.993850	-96.520017
CRY-014-09	7/11/2009	Marshall	Elm Creek	2	Kansas-Lower Republican	10270205	39.711367	-96.620967
CRY-015-09	7/12/2009	Pottawatomie	Spring Creek	1	Kansas-Lower Republican	10270205	39.471967	-96.522083
CRY-016-09	7/12/2009	Pottawatomie	Hise Creek	1	Kansas-Lower Republican	10270102	39.515317	-96.202633
CRY-017-09	7/13/2009	Pottawatomie	Lost Creek	2	Kansas-Lower Republican	10270102	39.275067	-96.184250
CRY-018-09	7/14/2009	Shawnee	Halfday Creek	2	Kansas-Lower Republican	10270102	39.153500	-95.706833
CRY-019-09	7/22/2009	Atchison	Negro Creek	2	Kansas-Lower Republican	10270103	39.537583	-95.533783
CRY-020-09	7/23/2009	Atchison	Nebo Creek	3	Kansas-Lower Republican	10270103	39.446600	-95.553117
CRY-021-09	7/23/2009	Leavenworth	Buckhorn Creek	2	Kansas-Lower Republican	10270104	39.368367	-95.094200
CRY-022-09	7/24/2009	Jefferson	Honey Creek	1	Kansas-Lower Republican	10270103	39.273883	-95.285400
CRY-023-09	7/25/2009	Douglas	Washington Creek	3	Kansas-Lower Republican	10270104	38.879000	-95.316850
CRY-024-09	7/26/2009	Johnson	Camp Creek	1	Kansas-Lower Republican	10270104	38.898233	-94.921383
CRY-025-09	7/2/2009	Rawlins	Beaver Creek	1	Upper Republican	10250012	39.678644	-101.224550
CRY-026-10	6/10/2010	Cloud	Whites Creek	1	Kansas-Lower Republican	10250017	39.554167	-97.808650
CRY-027-10	6/10/2010	Republic	Beaver Creek	2	Kansas-Lower Republican	10250017	39.769783	-97.859850
CRY-028-10	6/11/2010	Cloud	Buffalo Creek	3	Kansas-Lower Republican	10250017	39.596717	-97.781000
CRY-029-10	6/11/2010	Cloud	Trib. To Republican River	1	Kansas-Lower Republican	10250017	39.576733	-97.613067
CRY-030-10	6/12/2010	Cloud	Elm Creek	3	Kansas-Lower Republican	10250017	39.513594	-97.516867

Appendix A. (continued)

<b>Site</b>	<b>Date</b>	<b>County</b>	<b>Stream</b>	<b>Order</b>	<b>Drainage Basin</b>	<b>HUC 8</b>	<b>Lat.</b>	<b>Long.</b>
CRY-031-10	6/29/2010	Marshall	Trib. to Hop Creek	1	Kansas-Lower Republican	10270205	39.833550	-96.731550
CRY-032-10	6/29/2010	Marshall	Mountain Creek	2	Kansas-Lower Republican	10270205	39.917033	-96.731367
CRY-033-10	6/30/2010	Marshall	Snipe Creek	3	Kansas-Lower Republican	10270205	39.769533	-96.427650
CRY-034-10	6/30/2010	Nemaha	Weyer Creek	2	Kansas-Lower Republican	10270205	39.770000	-96.145183
CRY-035-10	7/1/2010	Riley	Walnut Creek	3	Kansas-Lower Republican	10270205	39.410983	-96.810550
CRY-036-10	7/1/2010	Clay	Deadmans Creek	1	Kansas-Lower Republican	10270205	39.539133	-96.988200
CRY-037-10	7/2/2010	Geary	Dixon Creek	2	Kansas-Lower Republican	10250017	39.099550	-96.854750
CRY-038-10	7/12/2010	Cheyenne	Plum Creek	1	Upper Republican	10250003	39.842133	-101.764517
CRY-039-10	7/13/2010	Rawlins	Little Beaver Creek	1	Upper Republican	10250013	39.770820	-101.223217
CRY-040-10	7/28/2010	Nemaha	Delaware River	2	Kansas-Lower Republican	10270103	39.864117	-95.795183
CRY-041-10	7/28/2010	Nemaha	Craigs Creek	3	Kansas-Lower Republican	10270103	39.793333	-95.806850
CRY-042-10	7/28/2010	Nemaha	Trib. to Wolfley Creek	1	Kansas-Lower Republican	10270103	39.668033	-95.822467
CRY-043-10	7/29/2010	Jackson	N. Cedar Creek	3	Kansas-Lower Republican	10270103	39.387133	-95.626400
CRY-044-10	7/29/2010	Jefferson	Duck Creek	1	Kansas-Lower Republican	10270103	39.286183	-95.517050
CRY-045-10	8/9/2010	Shawnee	Wakarussa River	1	Kansas-Lower Republican	10270104	38.901183	-95.928183
CRY-046-10	8/9/2010	Shawnee	Lynn Creek	2	Kansas-Lower Republican	10270104	38.924883	-95.613767
CRY-047-10	8/10/2010	Leavenworth	Ninemile Creek	3	Kansas-Lower Republican	10270104	39.068183	-95.150350
CRY-048-10	8/10/2010	Leavenworth	Hog Creek	2	Kansas-Lower Republican	10270104	39.130214	-94.976050
CRY-049-10	8/11/2010	Atchison	Trib. to Camp Creek	1	Kansas-Lower Republican	10270104	39.521267	-95.231817
CRY-050-10	8/11/2010	Jefferson	Crooked Creek	3	Kansas-Lower Republican	10270104	39.363433	-95.285367
CRY-051-10	8/12/2010	Leavenworth	Ninemile Creek	2	Missouri	10240011	39.231433	-94.898900
CRY-052-10	8/17/2010	Pottawatomie	Pleasant Creek	3	Kansas-Lower Republican	10270102	39.319483	-96.462367
CRY-053-10	8/18/2010	Pottawatomie	Rock Creek	1	Kansas-Lower Republican	10270102	39.463783	-96.336150
CRY-054-10	8/19/2010	Jackson	Soldier Creek	3	Kansas-Lower Republican	10270102	39.503900	-95.967017
CRY-055-10	8/19/2010	Shawnee	Trib. To Mission Creek	1	Kansas-Lower Republican	10270102	39.050667	-95.870983
CRY-056-11	5/17/2011	Decatur	N. Fork Prairie Dog River	1	Upper Republican	10250015	39.639900	-100.552783
CRY-057-11	5/17/2011	Decatur	Big Timber Creek	2	Upper Republican	10250015	39.744250	-100.292217

## Appendix A. (continued)

Site	Date	County	Stream	Order	Drainage Basin	HUC 8	Lat.	Long.
CRY-058-11	5/17/2011	Norton	Prairie Dog Creek	3	Upper Republican	10250015	39.777683	-100.058350
CRY-059-11	5/18/2011	Decatur	Sappa Creek	1	Upper Republican	10250011	39.890583	-100.403200
CRY-060-11	5/18/2011	Decatur	Sappa Creek	2	Upper Republican	10250011	39.956700	-100.312433
CRY-061-11	5/18/2011	Decatur	Sappa Creek	3	Upper Republican	10250011	39.970883	-100.215917
CRY-062-11	5/19/2011	Rawlins	Middle Fork Sappa Creek	2	Upper Republican	10250010	39.704003	-100.815117
CRY-063-11	5/23/2011	Rawlins	N. Fork Beaver Creek	3	Upper Republican	10250013	39.821617	-101.097233
CRY-064-11	5/23/2011	Rawlins	N. Fork Beaver Creek	2	Upper Republican	10250013	39.842633	-101.203367
CRY-065-11	5/24/2011	Rawlins	Trib. to Beaver Creek	1	Upper Republican	10250014	39.873033	-100.953917
CRY-066-11	5/30/2011	Riley	Kings Creek	2	Kansas-Lower Republican	10270101	39.114983	-96.610633
CRY-067-11	5/30/2011	Riley	Wildcat Creek	3	Kansas-Lower Republican	10270101	39.202267	-96.682867
CRY-068-11	5/31/2011	Morris	Clarks Creek	3	Kansas-Lower Republican	10270101	38.761483	-96.867783
CRY-069-11	5/31/2011	Morris	Trib. to Clarks Creek	1	Kansas-Lower Republican	10270101	38.782867	-96.846133
CRY-070-11	5/31/2011	Morris	Mulberry Creek	2	Kansas-Lower Republican	10270101	38.797500	-96.787567
CRY-071-11	6/1/2011	Wabaunsee	W. Branch Mill Creek	3	Kansas-Lower Republican	10270102	38.973950	-96.339783
CRY-072-11	6/1/2011	Wabaunsee	Spring Creek	2	Kansas-Lower Republican	10270102	38.988181	-96.416619
CRY-073-11	6/6/2011	Nemaha	Illinois Creek	1	Missouri	10240007	39.721017	-96.053567
CRY-074-11	6/6/2011	Nemaha	S. Fork Nemaha River	2	Missouri	10240007	39.702267	-96.014267
CRY-075-11	6/7/2011	Nemaha	Negro Creek	2	Missouri	10240007	39.927780	-96.202510
CRY-077-11	6/8/2011	Nemaha	Tennessee Creek	1	Missouri	10240007	39.798233	-96.096933
CRY-078-11	6/8/2011	Nemaha	Fisher Creek	3	Missouri	10240007	39.820800	-96.067533
CRY-079-11	6/8/2011	Nemaha	Harris Creek	3	Missouri	10240007	39.842883	-96.005317
CRY-080-11	6/8/2011	Nemaha	Trib. to Deer Creek	1	Missouri	10240007	39.899383	-95.926450
CRY-081-11	6/9/2011	Nemaha	Rock Creek	3	Missouri	10240007	39.978900	-95.799900
CRY-082-11	6/9/2011	Nemaha	Trib. to Pony Creek	1	Missouri	10240008	39.946433	-95.807383
CRY-083-11	6/13/2011	Brown	Spring Creek	3	Missouri	10240008	39.854900	-95.714600
CRY-084-11	6/13/2011	Brown	Terrapin Creek	2	Missouri	10240008	39.928400	-95.690167
CRY-085-11	6/14/2011	Brown	Spring Branch	1	Missouri	10240008	39.914600	-95.546167

## Appendix A. (continued)

Site	Date	County	Stream	Order	Drainage Basin	HUC 8	Lat.	Long.
CRY-086-11	6/14/2011	Brown	Noharts Creek	2	Missouri	10240008	39.957533	-95.489333
CRY-087-11	6/15/2011	Brown	Trib. to Pony Creek	2	Missouri	10240008	39.978483	-95.620983
CRY-088-11	6/15/2011	Brown	Roys Creek	3	Missouri	10240008	39.900017	-95.409583
CRY-089-11	6/15/2011	Doniphan	Mill Creek	2	Missouri	10240005	39.885850	-95.273167
CRY-090-11	6/16/2011	Doniphan	Mission Creek	2	Missouri	10240005	39.886967	-95.223183
CRY-091-11	6/28/2011	Doniphan	Charlie Creek	1	Missouri	10240005	39.783933	-95.295517
CRY-092-11	6/28/2011	Brown	S. Fork Wolf River	3	Missouri	10240005	39.699586	-95.395750
CRY-093-11	6/28/2011	Atchison	Clear Creek	2	Kansas-Lower Republican	10270103	39.644317	-95.426783
CRY-094-11	6/29/2011	Geary	Swede Creek	1	Kansas-Lower Republican	10270101	39.050817	-96.577900
CRY-095-11	6/29/2011	Geary	Humboldt Creek	3	Kansas-Lower Republican	10270101	38.933783	-96.603150
CRY-096-11	6/29/2011	Riley	Silver Creek	2	Kansas-Lower Republican	10270101	39.261750	-96.753558
CRY-097-11	6/29/2011	Riley	Wildcat Creek	1	Kansas-Lower Republican	10270101	39.351500	-96.871483
CRY-098-11	6/30/2011	Clay	Spring Creek	2	Kansas-Lower Republican	10250017	39.471967	-97.090350
CRY-099-11	6/30/2011	Washington	Petes Creek	3	Kansas-Lower Republican	10250017	39.697283	-97.153250
CRY-100-11	6/30/2011	Republic	Trib. to East Creek	1	Kansas-Lower Republican	10250017	39.726033	-97.532267
CRY-101-11	7/6/2011	Smith	Walnut Creek	1	Kansas-Lower Republican	10250016	39.962200	-98.777567
CRY-102-11	7/6/2011	Smith	Pawnee Creek	2	Kansas-Lower Republican	10250016	39.890717	-98.663667
CRY-103-11	7/6/2011	Jewell	Trib. to White Rock Creek	1	Kansas-Lower Republican	10250016	39.871883	-98.405100
CRY-104-11	7/7/2011	Jewell	Spring Creek	2	Kansas-Lower Republican	10250016	39.872017	-98.196300
CRY-105-11	7/7/2011	Jewell	Big Timber Creek	3	Kansas-Lower Republican	10250016	39.871500	-98.160267
CRY-106-11	7/7/2011	Jewell	Branch Courtland Canal	1	Kansas-Lower Republican	10250016	39.957733	-97.934067
CRY-107-11	7/8/2011	Republic	Spring Creek	3	Kansas-Lower Republican	10250016	39.941900	-97.910750
CRY-108-11	7/8/2011	Republic	Otter Creek	2	Kansas-Lower Republican	10250016	39.925450	-97.825417
CRY-109-11	7/8/2011	Republic	Dry Creek	3	Kansas-Lower Republican	10250016	39.869017	-97.819583
CRY-110-11	7/8/2011	Republic	N. Fork Mill Creek	1	Kansas-Lower Republican	10270207	39.885417	-97.557117
CRY-111-11	7/9/2011	Washington	Riddle Creek	3	Kansas-Lower Republican	10270207	39.873883	-97.133583
CRY-112-11	7/13/2011	Republic	Rose Creek	3	Kansas-Lower Republican	10270207	39.942950	-97.626867

Appendix A. (continued)

<b>Site</b>	<b>Date</b>	<b>County</b>	<b>Stream</b>	<b>Order</b>	<b>Drainage Basin</b>	<b>HUC 8</b>	<b>Lat.</b>	<b>Long.</b>
CRY-113-11	7/13/2011	Republic	Cherry Creek	2	Kansas-Lower Republican	10270207	39.914883	-97.405150
CRY-114-11	7/14/2011	Washington	Trib. to Mill Creek	1	Kansas-Lower Republican	10270207	39.906050	-96.993683
CRY-115-11	7/14/2011	Washington	Knedlik Creek	1	Kansas-Lower Republican	10270207	39.783000	-96.856833
CRY-116-11	7/14/2011	Washington	Camp Creek	2	Kansas-Lower Republican	10270207	39.682467	-96.843717
CRY-117-11	7/15/2011	Washington	Cottonwood Creek	2	Kansas-Lower Republican	10270207	39.885600	-96.858283
CRY-118-11	7/15/2011	Washington	Ash Creek	3	Kansas-Lower Republican	10270207	39.771033	-97.068017
CRY-119-11	7/19/2011	Leavenworth	Salt Creek	3	Missouri	10240011	39.347917	-94.990533
CRY-120-11	7/19/2011	Leavenworth	Little Plum Creek	1	Missouri	10240011	39.404467	-95.013667
CRY-121-11	7/20/2011	Atchison	Brewery Creek	2	Missouri	10240011	39.544417	-95.141900
CRY-122-11	7/20/2011	Atchison	Little Walnut Creek	2	Missouri	10240011	39.470550	-95.110433
CRY-123-11	7/20/2011	Doniphan	Coon Creek	1	Missouri	10240005	39.790733	-95.132650
CRY-124-11	7/20/2011	Atchison	Trib. to Independence Creek	1	Missouri	10240011	39.624150	-95.162300
CRY-125-11	7/21/2011	Doniphan	Trib. to Walnut Creek	1	Missouri	10240011	39.740367	-95.038700
CRY-126-11	7/21/2011	Doniphan	Peters Creek	3	Missouri	10240011	39.779433	-95.006033
CRY-127-11	7/21/2011	Doniphan	Ryans Branch	3	Missouri	10240005	39.783900	-95.223350
CRY-128-11	7/22/2011	Doniphan	Cedar Creek	3	Missouri	10240005	39.914833	-95.302083
CRY-129-11	7/21/2011	Brown	Trib. to Buttermilk Creek	1	Missouri	10240005	39.708917	-95.434017
CRY-130-11	5/19/2011	Rawlins	N. Fork Sappa Creek	1	Upper Republican	10250010	39.699067	-101.000289
CRY-131-11	5/19/2011	Decatur	S. Fork Sappa Creek	3	Upper Republican	10250010	39.756086	-100.592061
CRY-132-11	5/20/2011	Rawlins	N. Fork Driftwood Creek	1	Upper Republican	10250004	39.944631	-101.293117
CRY-133-11	5/20/2011	Rawlins	Burntwood Creek	2	Upper Republican	10250004	39.930439	-101.359758
CRY-134-11	5/20/2011	Rawlins	S. Fork Driftwood Creek	3	Upper Republican	10250004	39.963450	-101.018108
CRY-135-11	5/24/2011	Rawlins	Beaver Creek	2	Upper Republican	10250014	39.901608	-100.810103
CRY-136-11	5/24/2011	Decatur	Beaver Creek	3	Upper Republican	10250014	39.932186	-100.645881